QUICK DETERMINATION OF ACTUAL OIL CONTENT IN OIL PALM FRUIT BUNCH USING NEAR INFRA RED (NIR) SCANNING SPECTROMETER

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ABSTRACT

This research was being carried out to determine the oil contents of oil palm fruits in fastest possible time and to determine the effects of bunch weight (ranges from <20kg, 20-29kg, 30-39kg, 40-49kg and 50-59kg) and palm tree ages (ranges from 8-12years, 13-20years and >21years) on oil contents of oil palm fruits. The oil contents were determined using conventional method and the Near Infrared Spectrometer (NIRS). The other objective of this research is to improve the quality of the incoming fresh fruit bunch into Palm Oil Mill. The recent problem in the industry is to resolve the oil content dispute between the oil mill owners and fruit owners in fastest possible time, in order for both parties to directly determine the price based on the actual percentage of oil contents in the oil palm fruits. For the parameters that have been studied, by using the conventional methods, the results shown that the bunch weight of 30-39kg and the tree ages of 8-12 years old have the highest oil contents. Therefore, by using the Near Infrared Spectrometer, it will be used to provide faster and reliable results and it will be expected to replace the conventional methods as it has potential to reduce time and energy-consuming in years to come. In the future, the oil palm mills will only have to pay the right price for the right quality of the oil palm fruits.

ABSTRAK

Kajian ini dijalankan untuk mendapatkan jumlah kandungan minyak buah kelapa sawit dalam kadar yang paling singkat dan untuk melihat kesan berat tandan kelapa sawit (dibahagikan kepada beberapa kumpulan iaitu kurang daripada 20kg, 20-29kg, 30-39kg, 40-49kg dan 50-59kg) dan kesan umur pokok kelapa sawit (dibahagikan kepada beberapa kumpulan iaitu 8-12 tahun, 13-20 tahun dan 21 tahun ke atas) terhadap kandungan miyak dalam buah kelapa sawit. Kandungan minyak diukur menggunakan dua kaedah iaitu kaedah lama dan Spektrometer Infrared Jarak Dekat (NIRS). Objektif lain kajian ini adalah untuk memperbaiki kualiti buah-buahan kelapa sawit yang akan diproses di dalam mesin penyingkiran kelapa sawit (milling process). Masalah terkini yg dihadapi dalam industri adalah untuk cara untuk mendapatkan kandungan minyak dalam kadar segera bagi memudahkan pemiik kilang pemprosesan kelapa sawit dan pekebun kelapa sawit mendapatkan harga yang setimpal dengan nilai sebenar peratusan kandungan minyak di dalam buah sawit. Bagi parameter-parameter yang telah dikaji, dengan menggunakan kaedah pengekstrakan dan penyulingan, keputusan menunjukkan bahawa berat 30-39kg dan umur pokok sawit 8-12tahun mempunyai kandungan minyak paling tinggi. Oleh itu, dengan menggunakan Spektrometer Infrared Jarak Dekat, ia akan digunakan untuk memberi keputusan dengan lebih cepat dan lebih tepat. Ia juga diharapkan dapat menggantikan kaedah lama kerana ia mempunyai potensi untuk mengurangkan masa dan tenaga. Bagi masa akan datang, pemilik kilang hanya perlu membayar nilai sebenar untuk kualiti buah sawit yang ditawarkan.

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CHAPTER 1

INTRODUCTION

1.1 Background

The oil palm plantation is one of the commercial agriculture as it is important in the production of crude palm oil. The mature trees of oil palm are single-stemmed and can grow up to 20 m tall. The palm fruit takes around five to six months to mature from pollination to maturity. Each fruit is made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix; a central nut consisting of a shell (endocarp) and the kernel. The fruit is reddish and it is about the size of a large plum and it grows in large bunches. Each bunch of fruit weighs around 40 to 50 kg when they are ripe.

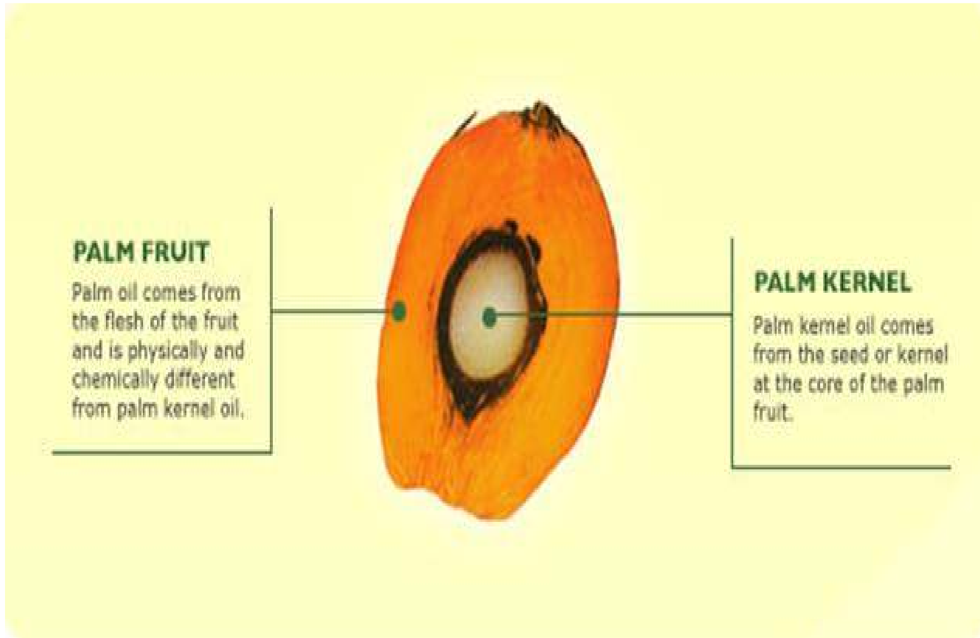

Figure 1.1: The Palm Oil Source

Malaysia produces 14 million metric tonnes of oil palm annually (2004 world output 30.6 metric tonnes crude palm oil) from about four million hectares oil palm plantations. The annual production per hectare average is at 10 metric tonnes of fruit which yields 3,000 kg of pericarp oil, 750 kg of seed kernels which yield 2500 kg of high quality palm kernel oil.

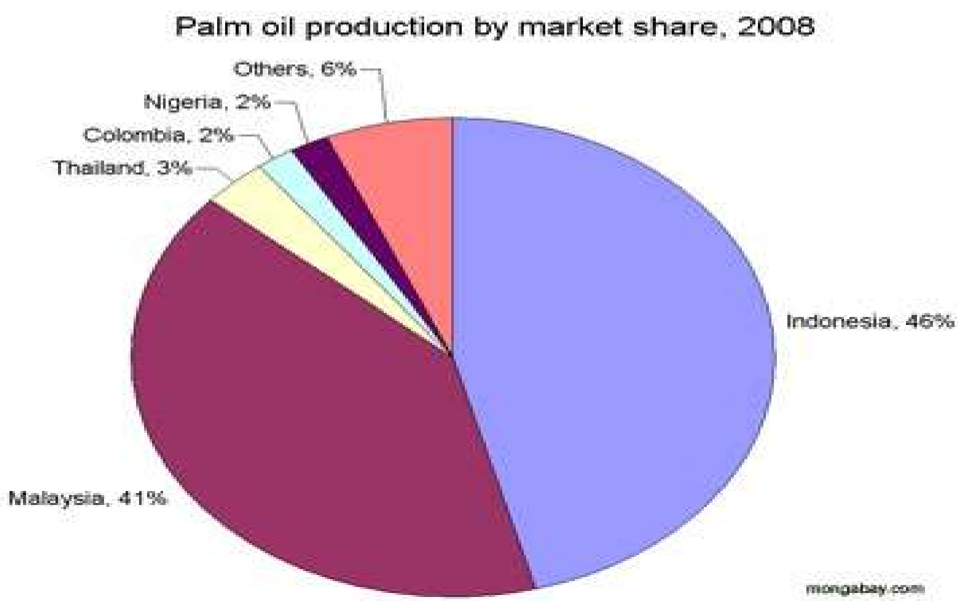

Figure 1.2: The Palm Oil Market in 2008

Fruit bunches are harvested regularly throughout the year, following harvesting standards set by the plantations. They are then transported to the palm oil mills where the crude oil palm and plant-kernels are produced by mechanical and physical extraction processes. Oil quality is maintained by careful harvesting of fruits at the optimum stage of ripeness, minimal handling of fruits during transportations and proper processing conditions during oil extraction.

Figure 1.3: Oil Palm Bunch

Figure 1.4: Oil Palm Fruit

The determination of actual oil content in oil palm bunch is in stage of development as it is still improving from time to time using different methods. The topic is chosen because the development in determining the oil content of palm bunch is a great opportunity to discover the better ways to analyze it with less time and energy needed. Some of the researchers started using the analytical equipments such as Nuclear Magnetic Resonance (NMR) and Differential Scanning Calorimetry (DSC). Though it is proven to be a success, they showed the methods can be improved in many aspects and they are still impractical for large numbers of big bunches. Hopefully with my research using Near Infrared Scanning (NIR) Spectrometer, it provides new discovery that is yet to be found.

The physical analysis is chosen in my research because of the high number of samples need to be analyzed daily, chemical analysis is too time-consuming. Therefore, by using the NIR Spectrometer, we can get the rapid determination of actual oil content in oil palm bunch. NIR Spectrometer is a spectroscopic method which uses the near infrared region of the electromagnetic spectrum which ranges from 800 to 2500 nm. NIR spectrometer is based on molecular overtone and combination vibrations. It can typically penetrate much farther into a sample than mid infrared radiation. It also can be very useful in probing bulk material with little or no sample preparation.

1.2 Problem Statement

The free fatty acids (FFAs) are released naturally in crude palm oil and they can be increased by the action of enzymes in the palm fruit or by microbial lipases. If they are increased in the palm bunch fruit, the oil content would be decreased and it would affect the quality of palm oil produced which cause the oil loss in oil palm fruit bunch. During the whole milling process, the content of free fatty acids can be increased including the transportation time taken of oil palm bunches to the factory. This results in Malaysian Palm Oil Board (MPOB) standardizes the free fatty acids (FFA) content is 5% maximum in crude palm oil. Malaysia recently produced 20 to 21% crude palm oil from world production palm oil. If we handle the process of milling oil palm fruit bunches, we would be expected to get 25% actual oil production, rather than having only 21% to 23% in oil milling production.

The grading of fruit bunch quality is as important as we want to know the oil content in each incoming fresh fruit bunches. If the fruit is low in oil content, it means that it is low in quality too. Nowadays, industrial factory faces the low content of oil in palm oil bunches that come from oil palm plantations as the harvested fresh fruit bunches are still young. The owner of plantations only thinks of the profits instead of worrying about the contents of oil in the harvested fruit bunches. Thus, the grading of fruits quality is important and it shows that if we could get the actual oil content in the incoming fresh fruit bunches as quickly as possible, the industrial factory would get to know that they harvest only the best quality and highly rich in oil fruit bunches.

From the previous researches done before, the methodology analysis chemically is too much time spent and energy-consuming. In industry, it is very important to save time and energy as it only costs them money if they spent too much on determining the oil content in each fresh fruit bunches. Therefore, it is very recommendable to try using only the physical scanning instead of chemical analysis which is too time-consuming because of the number of samples needed to be analyzed daily.

1.3 Objectives of the Study

This research is done basically to find the solutions to the problems that occurred in the industry recently. Therefore, based on the aforementioned introduction and problem statements, the objectives of this study are:

- To estimate oil contents in oil palm fruit bunch for a given batch in fastest possible time.

- To improve quality of the incoming fresh fruit bunch into Palm Oil Mill.

- To determine the effects of bunch weight and palm tree ages on oil contents of oil palm fruits.

1.4 Scope of Study

In order to achieve the objectives stated above, the following scopes of study have been drawn.

(i) The quantitative analysis of oil and other nutrients contents in oil palm fruit bunch.

(ii) Study on qualitative analysis of palm oil fruit bunch and how to improve them.

(iii) Study the effects of bunch weight and palm tree ages on the oil content and oil extraction rates. The ranges of palm tree ages are 2-4 years, 5-7 years, 8-12 years, 12-20 years and lastly 21 years and above.

(iv) Study on ways of helping the mill to improve the oil extraction rate for the incoming fresh fruit bunch.

(v) The comparison of performance of the Near Infrared Spectrometer and other conventional methods.

1.5 Rationale and Significance

Based on the research scopes mentioned above, the following rationale and significance that we could get have been outlined.

(i) Using Near Infrared Scanning Spectrometer, we expect to get the detailed information on the actual oil and other nutrients contents in oil palm fruit bunch.

(ii) Besides that, from this research study, it would help the mill to improve the oil extraction rate which is really important for palm oil production industry.

(iii) This research study also hopefully would help to improve the quality of oil palm fruit bunch as well as standardizing them.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Oil palm is one of the most important commercial agriculture in Malaysia. The annual production of Malaysia is 14 million metric tonnes from about four million hectares oil palm plantations. Palm oil is obviously the most important product of the oil palm and it is currently the world's main edible oil also used for soap making. It is used widely in industry for soap and table fats such as margarine and for the production of cosmetics in many countries worldwide (Owolarafe, O.K., Olabige, M.T. & Faborode M.O., 2005).

Figure 2.1: The Oil Palm Plantation

The interaction of several factors such as climate, soil, biotic environment, plant material genetic and technical of culture greatly influenced the growth of and productivity of oil palm fruit bunch from plant physiological aspect especially process of photosynthesis and usage of assimilate (Harahap *et al.*, 2000). The production of fruit bunches in oil palm is influenced by several factors, such as nutrients, water, carbohydrate supply and pollination (Hanif & Roslan, 2002). The original in bunch analysis was to use the variation in breeding and selection towards higher oil content. No equipment is currently reported that gives a direct precise measurement of the actual oil content in a given bunch in a single step. Complications arise because of the need to break down the hard lignified bunch frame work (stalk and spikelets), separate the numerous individual fruit and extract the oil from the mesocarp of a representative sample of these (I. Said, Tan, S.W. & Wood, B.S., 1984).

2.2 Research Background

Palm oil is obtained normally from the mesocarp of oil palm fruits. The oil content of palm fruits depends on the thickness of the mesocarp (palm oil). Researchers have found out that the quality of oil contents in oil palm fruits is related to the moisture contents in the fruits as well as the fruit ripeness. Fruit ripeness is one of the very important factors as it can be seen when the oil palm fruit is ripening, the oil content reaches the maximum while the moisture content reaches the minimum in the fruit (You,K.Y., Abbas, Z. & Khalid, K., 2010). The possibility of using the percentage of moisture content as a parameter to gauge the mesocarp ripeness and the harvesting time is because of the close relationship between the moisture and oil contents in the mesocarp.

Figure 2.2: The Mesocarp of Oil Palm Fruits

The amount of moisture contents in the oil palm fruits is successfully estimated first by the microstrip and coplanar sensors based on attenuation measurement. Unfortunately, the preparation of the fruit sample is very time-consuming as the sensors required labourious sample preparation in which the fresh mesocarp of the oil palm fruit has to be separated from the nut and crumbled to form a semi-solid sample (You,K.Y., Abbas, Z. & Khalid, K., 2010). Thinking of other way, thus, the open-ended coaxial probe is used as a moisture sensor to determine the moisture content of oil palm fruits of various fruit ripeness degrees at room temperature by using the reflection techniques.

Based on the number of studies conducted on different edible oils using Near Infrared (NIR) Spectroscopy, it can be postulated that NIR Spectroscopy could be applicable to measure some quality parameters of palm oil and its products. The use of analytical instrumentations is very common in analyzing the fats and oils. Throughout the years, many researchers have done their research regarding fats and oils using analytical instrumentations such as High-Performance Light Chromatography (HPLC) and Fourier Transform Infrared (FTIR). For instance, HPLC has been commonly used in separating and identifying the triglycerides and determining minor components in palm oil while FTIR is used to determine total unsaturation and and saponification value, monitor oxidation and determine the peroxide value in edible oils. NIR Spectroscopy is usually used in agriculture and the food industry. Recently, it has been known to analyze protein, moisture, fats and oils (Che Man, Y.B. & Moh, M.H., 1998). Compared to the conventional method, NIR Spectroscopy is capable of measuring hundreds of sample in a day and yet still meeting the trading specification. Moreover, by applying this technique, the amount of hazardous can be reduced dramatically as well as the cost of labour.

2.3 Concerns Regarding OER

Throughout the years, there are so many methods developed in order to determine the actual oil content in oil palm bunch in much less time and energy-consuming. One of them is by using the Nuclear Magnetic Resonance. The NMR usually used to study mixtures of analytes, to understand dynamic effects such as change in temperature and reaction mechanisms, and is an invaluable tool in understanding protein and nucleic acid structure and function. Most of them are using bunch analysis to determine actual oil content in a bunch. The standard sample analysis was found to be accurate and the precision acceptable for comparing groups of bunches. Nevertheless the bunch analysis method itself may give biased results with respect to the actual oil content in the bunch whether on a sample or a whole bunch basis (Chan, Chew, Goh, Hor & Soh, 2000).

The drastic and alarming declining trend in oil extraction ratios (OER) which began in 1992 and persisted through 1993 and after was reported by many principals' palm oil mills as with mills of other plantation groups in West Malaysia. Some researches done before have revealed that the prevailing trend of lower oil mill oil extraction rates could be explained to a large part by the actual low oil content of large bunches which, perhaps also, because of good fruit set, have a larger proportion of inner fruits bearing little oil (Chan, Chew, Goh, Hor & Soh, 2000). Mill and harvesting inefficiencies are unlikely to be the main contributing factors to the prevailing low oil mill oil extraction rates (OER) trend.

Figure 2.3: The Oil Palm Tree Ages of 5-7 Years Old

To determine the ripening of the oil palm fruits as well as the oil content in fruits is by using the conventional way of counting the number of fruits loose per bunch (Hartley, 1998). The fruit then are graded manually into their color just after the harvesting which establishes the grade and quality of the extracted oil. Color provides valuable information in estimating the maturity and examining the freshness of fruits. Color is the one of the most significant criteria related to fruit identification and fruit quality and is a good indicator for ripeness. The fruits, especially, in the agricultural field, we cannot estimate the fruit quality just by its shape or pattern. The fruit may have a different shape and pattern but the same level of quality. Currently, the grading system still analyzes the color of the fruit and obtains its quality based on the density of color. Many grading systems have been developed and practically used for fruits and vegetables.

As far as we know that most of the conventional methods that have been used to determine the oil contents of oil palm fruits are destructive and therefore, they cannot be applied. Some of these methods only rely on the measurement of fruit firmness, which is correlated to ripeness, by using penetrometer based on shape, feature and colors. The other ways include parameters that correlated to ripeness such as pH or spectral image analysis and the measuring levels of chemical species. Shape is one of the important visual quality parameters of fruits. It is a feature and is easily comprehended by human but using computer, the shape is difficult to be quantified and defined (Alfatni, M.S.M, Shariff, A.R.M & Shafri, H.Z.M., 2008). The investigation of correlation between the oil content in the oil palm fruit and the color of the individual fruit of oil palm fruit brings out help in increasing the efficiency of quality harvesting and grading of oil palm Fresh Fruit Bunches (FFB).

Usually the bunch analysis is conducted for the palms after they attain the stable yield and hence, the activity can be started only after the palms attain an age of 10 years. However, in most of the cases, the comparative performance matters for a researcher and hence the juvenile palms of the same age can be selected for bunch analysis for a specific experiment. Nevertheless, sampling of the bunch should be carried out during the same period or same season. Otherwise, the error due to seasonal variation should be taken into consideration.

Figure 2.4: The Oil Palm Seeds

A few earlier studies suggested that the maximum oil formation in a bunch is achieved with the first loose ripe fruit. Methods based on biochemical and colour changes did not provide statistical backing (Aziz Ariffin, 1985) while those based on bunch analysis on bulked samples of bunches of different loose fruit classes tended to be prone to sampling errors arising from variable bunch sizes, weights and origins (Rajanaidu, *et al.*, 1985). According to Chan, Chew, Goh, Hor and Soh (2000), thrugh their experiment to determine the actual oil content of commercial bunches sent to the mills, it showed that the bunches indeed had inherently lower oil contents and that the low OER could not be blamed on poor oil recoveries as a result of declines in field and mill efficiencies. The processed bunches were of the highest quality and the oil losses were within industry standards.

Figure 2.5: The Different Colors of Oil Palm Fruits

Many studies have been carried out to investigate the parameters which could affect oil extraction rate. These parameters include the structure and composition of the fruit bunch. To give a clearer understanding of the oil extraction rate problem in the palm oil industry, there should be an understanding of bunch composition for different palm age categories (Yosri, M. S., Chang, A. K. & Nazarulhisyam, S., 2005). Palm trees age and layers of fruitlets of fresh fruit bunch are believed to be directly related to oil extraction rate. From the previous studies indicated that oil per bunch may decline with age and it is also believed that the different layers of fruitlets have different oil contents. The younger palms generally is said to give the highest oil in bunch as compares to the prime and old palm categories, even though the difference may not be very large or statistically significant.

According to an article written by Ho, C.Y., Gan, L.T., Joseph Tek, M.C., Singh, S., Dennis Hon and Tan, M.C. (1996), bunch analysis and commercial batch processing results confirmed that bigger bunches from older palms had distinctly lower oil content. Seasonal conditions such as rainfall have a direct effect on oil extraction rates as con tenuous high rainfall adversely affected weevil pollination. This resulted in poor fruit set about 5 ½ half months later. The effect was more pronounced in isolated young plantings. During the affected period, fully mature palms recorded lower bunch weight and kernel content. At the 1993 National Seminar, the probable biological, agronomic, environmental and management factors that could affect oil extraction rates were discussed thoroughly. It was agreeable that milling losses were largely within acceptable limits. The increasing labour shortage in the plantation industry were deemed to be the main cause of the observed decline in national oil extraction rates as it has caused the deteriorating standards in harvesting and loose fruit collection. The measures adopted by the industry were proven to unsuccessful in arresting the declining OER trend.

OER and free fatty acids (FFA) level are two main indicators of milling efficiency which can indirectly influence the profitability of any plantation enterprise. The national standard stipulates that the theoretical extraction rate is between 21-23% and the FFA content should not be higher than 5%. Usually there had been increasing pressure from top managements on the estates and mills in the industry to tighten up standards in order to arrest the declining trend in OER. The harvesting intervals, reflected by the changes in harvesting intervals, loose fruit losses in the field and bunch quality (Ho, C.Y., Gan, L.T., Joseph Tek, M.C., Singh, S., Dennis Hon and Tan, M.C., 1996). In fact, for every 1% of unripe bunches present, the OER will decrease by 0.13%, while the FFA content will increase linearly as the percentage of overripe bunches increases. In the recent years, the yields of oil palm reached a stagnant level due to unimproved planting materials which dominated the natural or semi wild groves from which the bulk of palm oil is produced. Hence, the first task to ensure quality in oil milling is to select a good quality of fresh fruit bunches for processing.

Besides the effects of palm trees ages and bunch weight on the OER, there is another effect that actually can affect the whole oil content in palm fruit bunch. The differences in OER between sites are likely due to soil, climatic and associated biological differences when management practices and planting materials are broadly similar. The primary effects of high and low rainfall were clearly reflected in the high and low OERs respectively 11 months later (Ho, C.Y., Gan, L.T., Joseph Tek, M.C., Singh, S., Dennis Hon and Tan, M.C., 1996). On-going investigations by several groups have identified the following primary contributing factors; (i) exceptionally high rainfall (more than 400 mm/month) and high number of rain days for two or more consecutive months; (ii) very high sex ratio (exceeding 90% and very low absolute number of male inflorescences per ha); (iii) low weevil population and activity associated with small number of male inflorescences and (iv) poor pollen viability under excessively wet conditions. During the affected months concerned, there is a significant drop in bunch weight of fruit bunches not only in young plantings but also from the older palms regardless of bunch numbers.

Despite Malaysia has the phenomenal success and a reputation for good efficient management, the average cost of production has been rising from time to time which represents an annual increase of about 4% per year. If this continues unattended, the industry may one day lose its competitiveness to other competing vegetable oils or become unsustainable (Sharma, M., 1999). In order to reduce the cost of production, the most effective means is by increasing oil yield per unit area. This can be achieved by directly increasing fresh fruit bunches, improving oil content of fruit bunches and improving oil recovery in the milling process. However, some of the oil palm plantations have failed to achieve good OER despite ensuring good crop quality, reducing field losses to a minimum and maintaining good milling efficiency, particularly where the bulk of the plantings are 16 years old and above.

Figure 2.6: Different Sizes and Shapes of Oil Palm Fruits

There is another parameter that should be taken note; that is the fruit size. The hypothesis was that if bunches had larger fruit size, then the outer layer should contribute a higher proportion of the total mesocarp to bunch and this may give a higher oil bunch ratio and the decline of oil content with increasing bunch size would be reduced.

2.4 The Industry

The industry is plagued by a serious shortage of workers with experienced and disciplined local labor being replaced by foreign workers. A large number of manual workers must have been brought into the industry, rarely with many experiences, as the production volume increases. Many estates or plantations are also forced to carry out afternoon contract harvesting to cope with the shortage of harvesters (Sharma, M., 1999). This is usually carried out with little or no supervision by the management of the estate. As a result, it is common to find poor crop quality landing at the mills apart from increasing field losses from uncollected loose fruits.